Assessment of ionospheric indices in the frame of ESA Space Weather Network activities

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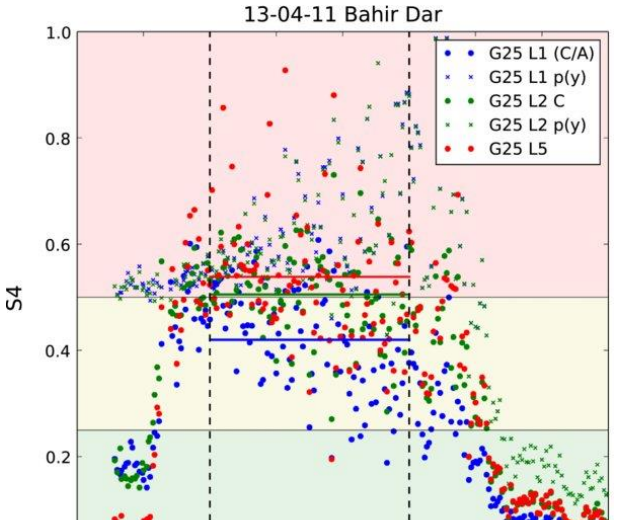
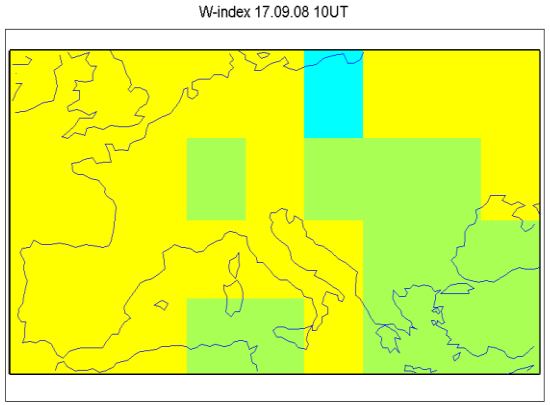
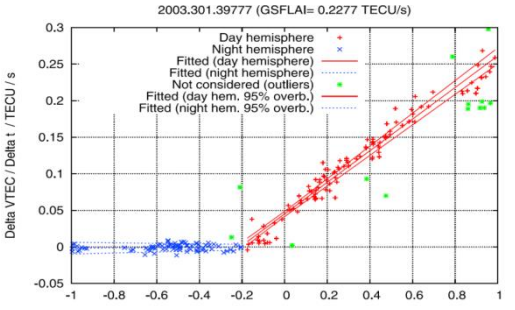
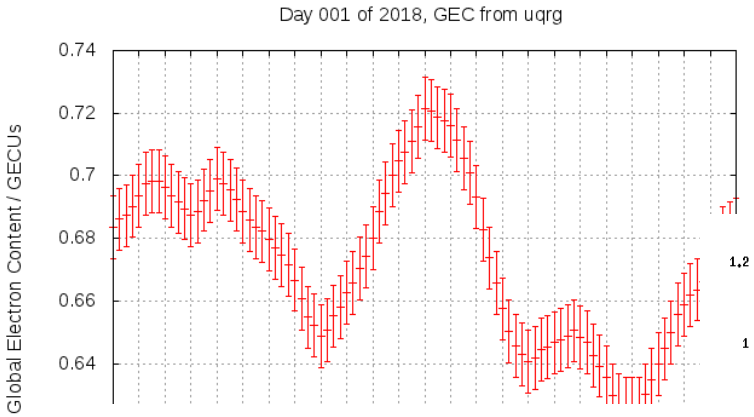
Introduction and Objectives

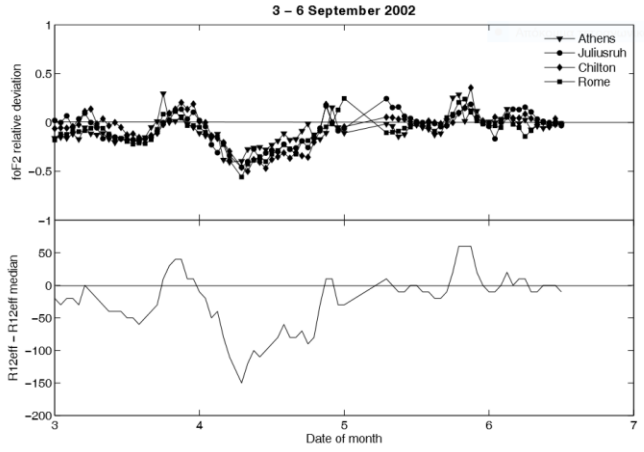
- generation of a catalogue of ionospheric indices their capabilities, performance and range
- generate a comprehensive knowledge on applicability of the currently available indices through:
  - dedicated review of ionospheric indices described in scientific journals
  - assessing the applicability of indices for different situations of ionospheric disturbances
  - assessing the applicability of indices for different situations of ionosphere impact on technical systems
- Support for generation of ionospheric scales → preparatory work

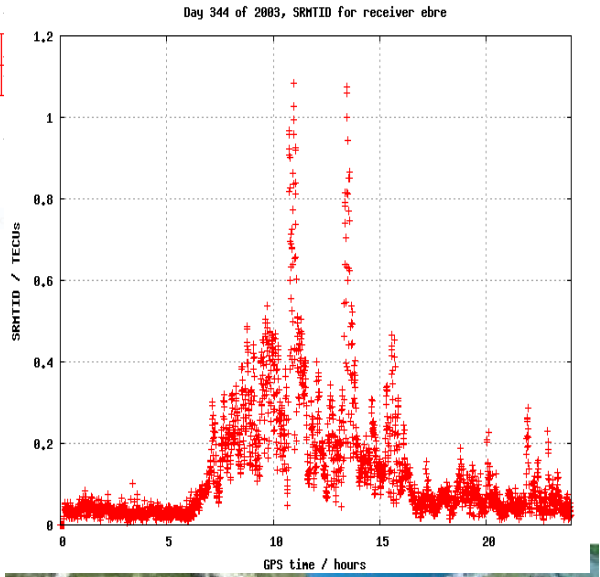












Description of indices

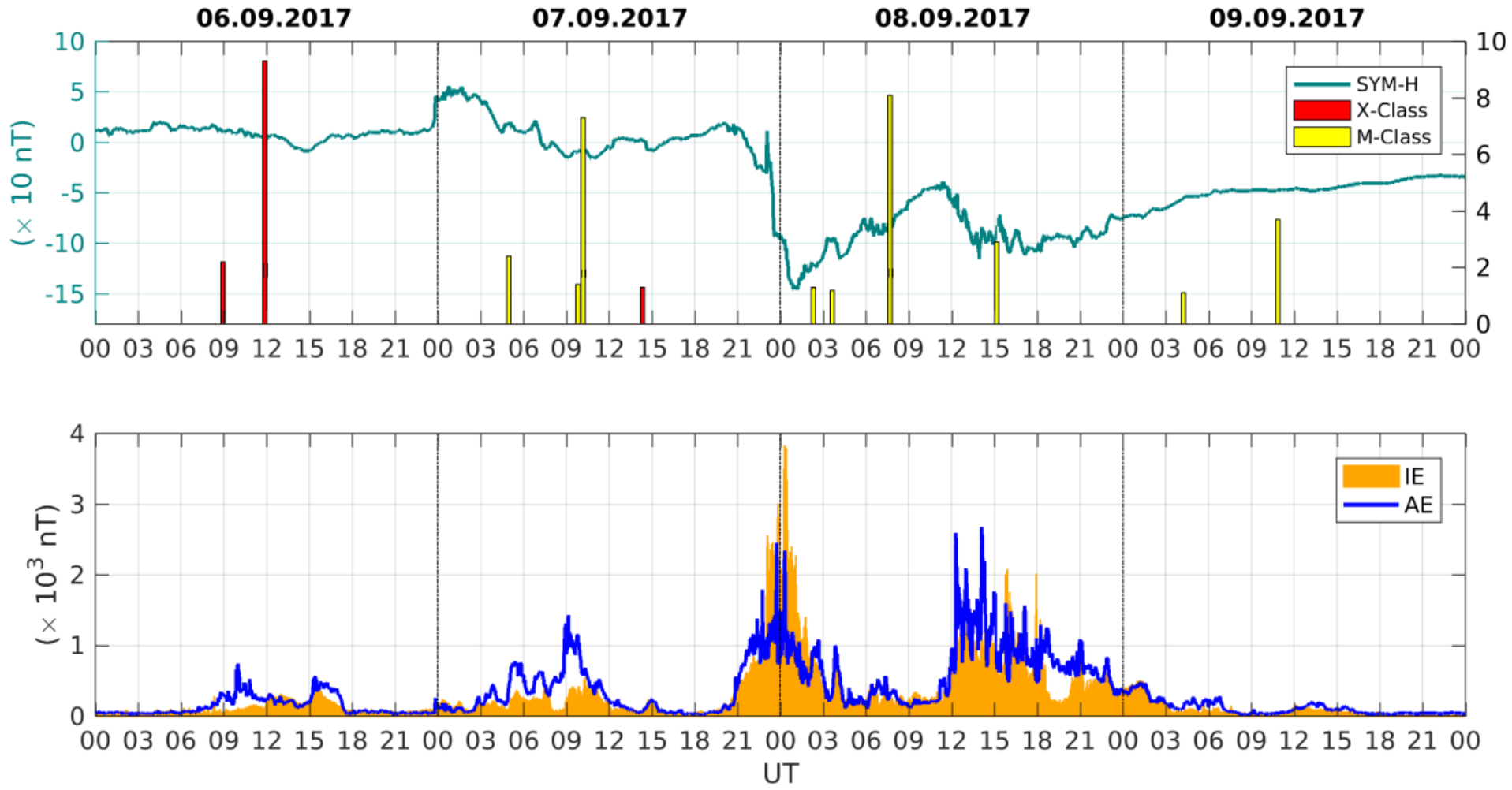
- 19 well known indices indices developed/ operated in Europe
- Based on **ionosphere observations**, mainly ionosondes and GNSS
- Sensible to different kinds of ionosphere perturbations

Index	Name
W-indes	Ionospheric Weather W index
DIAS R12eff	DIAS Effective Sunspot Number
ROTI/ ROTI@ground	Rate of Change of TEC Index
DIXSG	Disturbance Ionosphere Index – Spatial Gradient
SRMTID/SSMTID	Single Receiver Medium Scale Travelling Ionospheric Disturbance Index and Single Satellite Medium Scale Travelling Ionospheric Disturbance index
GEC/ dGEC	Global Electron Content (Rate)
SOLERA	SOLar Euv flux RAte GNSS proxy
SISTED	Sunlit Ionosphere Sudden TEC Enhancement Detector
IBI	Ionospheric Bubble Index
AATR	Along Arc TEC Rate
Dfu/ Dfl	DfoF2-upper and Dfl: DfoF2-lower
S4/ Sigma_Phi	Scintillation index
IG12	12-month-running mean of the ionospheric IG index
SIDX/ GIXP	Sudden Ionospheric Disturbance indeX, Gradient Ionosphere indeX

Desciption of indices

Temporal/ spatial resolution	Global	Regional/ Europe	1000 x 1000 km	100 x 100 km	At receiver location	other
1 month	IG12					
1 day						
1 hour	GEC/dGEC, Dfu/Dfl				AATR	
15 min	GEC/dGEC	$R12_{eff}$	W			
5 min				ROTI, ROTI@ground	AATR, SRMTID	SSMTID (at IPPs)
1 min	SOLERA, SISTED, $DIXSG_p$	SIDX, GIX		ROTI, ROTI@ground, DIXSG, S4, σ_ϕ	S4, σ_ϕ	
1 sec						IBI (at satellite orbit, $\approx$ 7 km)

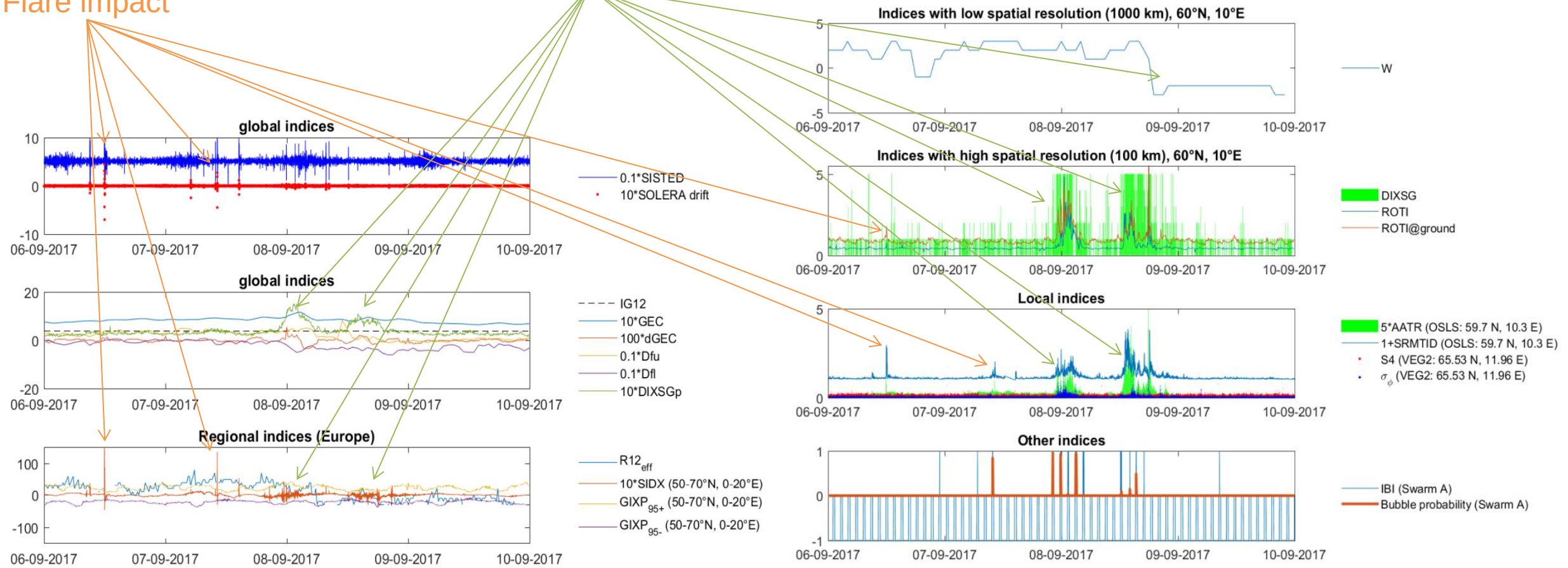
Case study September 2017 space weather event



Case study September 2017 space weather event

Storm related ionosphere perturbations

Flare impact



Use cases

Natural envirionment use cases

- Ionosphere response to solar flares
- Ionosphere response to radio bursts
- Ionosphere response to CME, CIR, etc
- Small scale irregularities (causing signal scintillation)
- Equatorial plasma depletions
- MSTID/ LSTID
- Planetary waves
- Gradients
- Ionosphere modelling
- Deviation from quiet conditions

Technical system and infrastructure use cases

- EGNOS system degradation
- Lost GNSS signal (loss of lock) at ground
- Lost GNSS signal (loss of lock) at LEO orbit
- Lost communication signals
- HF communication
- Performance degradation of network RTK
- Degraded positioning accuracy for stationary appl.
- Degraded positioning accuracy for mobile appl.
- Model degradation in single frequency positioning
- GBAS hazardous misleading information

Index application matrix

- Overview on applicability of the indices
- Based on the assessment of indices and use cases
- For each use case all applicable indices are indicated
  - Numbers indicate references to published applications
  - Asterisk indicates recommended but not yet published application of indices

	use case	AATR	Dfu/Dfl	DIXSG	GEC	GIX	IBI	IG12	$R12_{eff}$	ROTI	$S4/\sigma_\phi$	SIDX	SISTED/SOLERA	SRMTID/SSMTID	W-index
Natural	Solar flares									[31]		[21]	[22]		
	Solar radio bursts														
	Small scale irregularities						*			[9]	[35, 34]				
	Equatorial plasma depletions						[5]								
	MSTIDs/ LSTIDs													[37]	
	Planetary waves														
	TEC gradients	*		[3]		[21]									
	Ionosphere modelling							[6]	[38]						
	Deviation from quiet conditions		[2]						[8]						[26]
	CME, CIR, etc.	[1]	[2]	[3]	*	*	*		[8]	[9]	[35, 34]	*			[26]
	SEP														
Technical	SBAS/EGNOS	[1, 43]	*	*	*	[21]	*		*	[39, 40, 43]	[42, 43]	[21]	[37]	*	*
	LoL GNSS						[48]			[9]	[47]				
	Radio Communication		*		*				*	*	*		*	*	*
	RTK performance	*		*							[35]	[35]		[37]	
	Stationary GNSS application									[52]					
	Mobile GNSS application									[14]	[42]				
	Model degradation (SPP)														*
	GBAS impact			*		*								*	
	Polar Cap Absorption											*	*		

Summary and Conclusions

- A significant list of ionosphere indices has been analysed with respect to use cases
- Technical impact of ionospheric perturbations as well as the impact of natural effects on the ionosphere can be described with indices
- In many use cases there are already indices available which can be applied
- Some use cases do not have appropriate indices yet

- We need scales for quiet, moderate and severe conditions in the ionosphere
- Combination of indices recommended for individual use cases
- Definition of thresholds necessary (Technical impact is hard to describe, because it often depends on technical devices)

→ more indices and use cases can be complemented in future